Method for producing molded parts for low-voltage, medium-voltage and high-voltage switchgear

The invention relates to a method for production of insulating moldings for switching devices for low-voltage, medium-voltage and high-voltage, and to a switching device itself, as claimed in the precharacterizing clauses of patent claims 1, 2, 3 and 17.

The components of the switching devices mentioned are subject to very stringent requirements. In addition to the required dielectric characteristics, mechanical characteristics such as cantilever strength, impact resistance and the inclination to form cracks, etc, are of importance at the same time.

Previous experience relating to this has indicated the possibility of crack formation in epoxy resin components and components composed of other insulating materials in switching devices such as these.

It is essential to avoid this. Efforts have already been made in the past to achieve this. Vacuum chambers and other parts which were installed in the dielectric moldings were encapsulated directly into the load-bearing enclosure composed of epoxy resin, together with their fixed and moving connections. In order to prevent crack formation in this case, the materials of the moldings are encapsulated jointly with a filling powder added to it composed of quartz powder or synthetic silica flour.

This procedure has been proven.

Furthermore, components have been encapsulated in silicone or polyurethane or a “soft” casting resin without any filling powder, in order to increase the

external dielectric strength.

The encapsulation technique means that the vacuum switching chamber and the inserted parts must be cushioned, for mechanical reasons, by means of an elastomer material before introduction into epoxy resin. The requirements for this material are:

- high dielectric strength
- good adhesion to the vacuum switching chamber (or to the inserted part)
- good adhesion to the surrounding epoxy resin
- adequate elasticity to absorb thermal stresses and mechanical stresses.

The purpose of this cushioning is to absorb stresses that are created in the component during production and operation of the epoxy resin components as a result of mechanical or thermal shrinkage.

The components have a correspondingly high total weight as a result of the high density of the filling powders or else filling powder mixtures that are normally used nowadays.

When using silicone or polyurethane, or "soft" casting resin without any filling powder, the mechanical strength of the completely encapsulated components is small, and is of a resilient nature.

Against this background, the invention is based on the object of improving a method of this generic type such that the stated disadvantages are overcome, while at the same time retaining the described advantages obtained.

The stated object is achieved for a method of this generic type by the characterizing features of patent

claim 1.

Other advantageous refinements are specified in the dependent claims 4 to 16.

With regard to a switching device of this generic type, the stated object is achieved by the characterizing features of patent claim 17.

Further advantageous refinements of the device according to the invention are specified in the other dependent claims.

The essence of the invention relating to the method is in this case that a mixture of balls with a statistical distribution of diameters of size Dx are introduced as a filler into the encapsulation compound. The use of balls, glass balls or hollow glass balls as a filler in epoxy resin or in plastics, or else a combination of balls and filling powders, allows the chemically dependent shrinkage during curing to be set to be considerably less than the values currently achieved in the references, and it is even possible to reduce the coefficient of expansion of the finished component. Higher packing densities are achieved with the use according to the invention of a mixture with statistical particle external diameters. The particles or particle matrix are or is thus denser, or are or is distributed more densely. This results in mechanically more-resistance direct encapsulation or direct encapsulation of parts and components.

The spherical filling material also increases the notch toughness of the cured encapsulation compound.

The unavoidable remaining mechanical shrinkage stresses in the component can be absorbed by the filled casting resin by the filler being in spherical form in the

epoxy resin, as a result of which the mechanical characteristic values of the corresponding mixture are comparatively considerably higher.

A further alternative method which can be used in its own right or together with the method mentioned above is the corresponding use of hollow balls. In conjunction with the initially mentioned measure, this would result in a mixture of solid and hollow balls. The exclusive use or joint use of hollow balls makes it possible to produce an insulator of low density, which allows the subsequent overall component to have a low total weight.

A further alternative which, however, can also be read as being optional in conjunction with the above claims may consist in that at least one switching chamber is provided with a cast surround composed of a first encapsulation compound, and is then encapsulated together with connections into a block composed of at least one second encapsulation compound such as silicone, soft epoxy or plastic.

Epoxy resin is used as the first encapsulation compound, and silicone, polyurethane, a polyurethane derivative or soft epoxy is used as the second encapsulation compound.

In this case, in a further advantageous refinement, it is now possible to provide for the particles to be incorporated both into the first and into the second encapsulation compound.

In one advantageous refinement, the balls or the hollow balls are composed of glass, or of ceramic, preferably of aluminum-nitride ceramic. A material which is suitable for use in electrical switching devices is thus chosen.

It is also advantageous for the filling level to be set to be between 50 and 90%. This allows optimum results to be achieved with regard to mechanical requirements and crack-prevention measures.

In a further advantageous refinement, other fillers are mixed with the ball and/or hollow ball mixture.

Commercially available cinder pastes or else primers can be applied to the glass surface in order to achieve better wetting of the glass balls or else hollow glass balls. In the future, a novel combination of different filling powders in the epoxy resin mixture will make it possible to encapsulate the inserted parts (for example vacuum switching chambers or other metallic or non-metallic inserted parts) without cushioning, or else directly with the epoxy resin mixture by means of such a combination.

In order to achieve optimum results, external diameter mixtures of the balls or hollow balls are firstly used with a bandwidth of 65 micrometers to 120 micrometers.

Furthermore, optimum results are also achieved with external diameters from 40 micrometers to 85 micrometers.

In a further advantageous refinement, the particles have a mean density of 0.2 g/cm^3.

In one advantageous refinement, the particles have a mean density of 0.37 g/cm^3.

Further refinements in which good mechanical and electrical characteristics can be achieved as a result are as follows:

- hollow balls with a diameter of up to 200 micrometers.

- hollow balls with an effective density between 0.1 and 0.6 g/cm^3.

- solid balls with a density between 2.0 and 7.0 g/cm^3.

The density of the hollow balls as mentioned above means the effective density, that is to say the weight per unit volume with regard to the cavity.

The features of the device according to the invention are designed in a corresponding manner.

A further aspect is the improvement of the thermal conductivity when heat is produced in the switchgear assemblies. This heat must be passed from the inside to the outside, that is to say it must be dissipated.

Fillers or additives with a high specific thermal conductivity are chosen for this reason. Overall, a material such as this or a component manufactured from it is considerably more suitable than epoxy resin or some other plastic on its own. At the same time, the particle filling according to the invention reduces the crack sensitivity and results in a good isolation effect.

First of all, irrespective of the additives, it is possible to provide enveloping overall encapsulation in silicone or in a soft epoxy casing, which surrounds the switching chambers on the one hand and the connections on the other hand.

The invention will be described in more detail in the following text and is illustrated in the drawing, in

which:

Figure 1 shows a pole part with a vacuum switching chamber,

Figure 2 shows a component according to Figure 1, in a three-phase version.

Figure 3 shows an embodiment with block encapsulation in, for example, silicone.

By way of example, Figure 1 shows a pole part of a switch gear assembly. In this case, a vacuum switching chamber 1 is encapsulated by a first encapsulation compound 10 composed of epoxy resin.

As already stated, the chosen encapsulation compound is preferably epoxy resin and, in the wording of the patent claims, is referred to as the first encapsulation compound. According to the invention, this can now also be provided with balls or particles of the stated size. The effect of reduction in the risk of crack formation according to the invention is achieved at the same time as good thermal conductivity. In order to achieve optimum thermal conductivity, the particles or balls are preferably composed of aluminum nitride. Aluminum oxides are also suitable, but the thermal conductivity of AlN is greater than that of Al_2O_3.

Figure 2 shows a three-phase switching arrangement for a three-phase supply. In this case, epoxy, silicone or polyurethane is used as the final enveloping material, that is to say as the second encapsulation compound 20, into which the pole parts together with the connections/busbars 2, which have been encapsulated with the first encapsulation compound, are inserted and are enveloped/encapsulated by the second encapsulation

compound 20. Injection-molding methods can also be used in this case. Epoxy, silicone or polyurethane is used. This is then provided with the filler, in the described manner.

The fillers, that is to say the balls, hollow balls and further fillers, are introduced into the stated material. A statistical distribution of selected particles and ball sizes leads to a high packing density.

This now means that a combination of different balls, glass balls or hollow glass balls is used as an additive to the epoxy resin compound in order to reduce internal stresses in epoxy resin components in the presence of inserted parts (for example vacuum switching chambers or other parts) and to absorb unavoidable mechanical stresses. The filling level governs the mechanical and thermal characteristics. This is preferably 50-90%. The density of the epoxy resin mixture is considerably reduced by the use of hollow glass balls. The mechanical strength of the component and of the encapsulation compound are increased by the addition of balls, glass balls or hollow glass balls to the silicone, polyurethane or "soft" casting resin.

The invention also provides for the additional mixing of further filling components with the balls in a corresponding mixture ratio, for example quartz powder, synthetic silica flour or Wollastonite.

A different thermosetting plastic molding (for example polyurethane) can also be used instead of epoxy resin.

In this case, the hollow glass balls can be kept in contact with one another in the encapsulation compound such that the epoxy resin, silicone or polyurethane in

consequence fills only the gaps between the hollow glass balls, without any bubbles.. The thermal coefficient of expansion decreases towards that of glass.

If a system composed of silicone or polyurethane, or a "soft" casting resin is chosen, then it is possible by the addition of balls, glass balls or hollow glass balls to achieve a considerable increase in the mechanical strength of the component. This will make it possible in the future to provide material mixtures such as these as construction materials for the encapsulation of mechanically stressed isolators (component) with the required attachment points. Furthermore, the use of hollow glass balls will make it possible to produce extremely "lightweight" components with high mechanical and dielectric strength.

One particular problem that arises in the production of solid insulation for an isolator block (for example for encapsulation of all the components of a switchgear assembly) is that the heat that is produced must be passed to the surrounding area outwards through the isolator in order to ensure that the temperature of the encapsulated components does not exceed a maximum permissible value. At the moment, this is achieved by the measure of the isolator wall thickness being small but adequate and/or by the fitting of a heat exchanger composed of metal (passing through the isolator at one point as far as the metal parts, or into the vicinity of a metal part).

A switchgear assembly with solid insulation contains not only the switching elements, for example the pole parts, but also a number of connections and electrical junctions which must themselves likewise have solid insulation and must be sealed dielectrically at the junction points by means of appropriate isolation

elements.

In contrast, all of the necessary components such as the vacuum switching chamber as an active switching element, a three-position switch - possibly in the form of a further vacuum chamber -, the power supply busbars, transformers and further components are introduced into an optimized volume. All of the equipment is then encapsulated in a mold to form a "block" or a unit, preferably using silicone rubber. In order to allow the heat to flow from the area inside the block that is created to the outside, a ceramic filler can be incorporated in the silicone. The filler can be incorporated in the silicone compound beforehand. Another option is impregnation of the filler, for example with silicone, in the evacuated mold.

The use of silicone as the encapsulation compound makes it possible to enclose an entire technical device with one isolator, without any crack formation.

The connections to a possible three-phase "block" are preferably provided by means of cables connected to commercially available plug connections of the respective plug sizes. The sockets are permanently connected and encapsulated in or on the "block". Casting resin components (pole parts, and the like) can also extend into the silicone compound in order to increase the mechanical strength in the area of the switching elements, as shown in the two sketches. An appropriate drive, for example, can be mounted on these from the outside. The other parts (power supply busbars, transformers, etc.) are mounted between the components. After application of appropriate adhesion promoters, an electrically "sealed" block can be produced with all the necessary components.

The heat flow which occurs inside the block can be passed to the block surface in particular by means of a filler composed of the material AlN (up to 220 W/mK). If a high filling proportion of this ceramic material is introduced into the silicone material, the thermal conductivity of the encapsulation compound can be increased considerably, and the dielectric performance can be kept at today's level, or can be increased. The heat flow can be dissipated to the exterior by means of appropriate enlargement of the surface area (ribs associated with convection in the surrounding air) and/or by means of cooling elements at appropriate dielectrically non-critical points.

If, for example, the filler is introduced directly into a mold which surrounds the components, comparatively "large" particle diameters can be chosen for the ceramic components. This means particle sizes, for example, in the range from 1 to 10 mm, preferably with a spherical shape in order to increase the notch toughness on the complete block. This is different to the situation of encapsulation with a prefabricated encapsulation compound. In this situation, appropriately finer particles must be chosen in order to ensure sufficiently low viscosity for the subsequent processes.

For simplicity, individual blocks can also be produced instead of an entire block in which all of the components are located. The use of individual blocks allows a maintenance-friendly and low-cost solution for repair purposes.

Figure 3 shows the transparent illustration of the incorporation of all the described elements in enveloping block encapsulation of the second encapsulation compound 20, for example with silicone or soft epoxy. In this case, both the switching chambers 1

and the connections or busbars 2 are also encapsulated. The physical arrangement of the pole parts 1 leads to mechanical stiffening of the block in the encapsulated block arrangement, although it is composed of the soft second encapsulation compound.

In a three-phase version, as shown in Figure 2, the blocks are separated from one another by means of intermediate plates 3, for heat dissipation.